INHIBITION-BASED FAN EFFECT IN CHILDREN ENGAGED IN LETTER AND COLOUR BLOB FLANKER TASKS

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Abstract

An inhibition-based fan effect was explored with two different negative priming tasks. Experiment 1 used a modified flanker-type colour blob task in both children and adults (Pritchard & Neumann, 2004), where two additional conditions were included (C2 and IR2). Each set of the colour blobs for the additional conditions consist of two distractor colours instead of one distractor colour. Experiment 2 used Navon's (1977) global-local letter task, where a global letter contains one, two, or three local letters as distractors to see if an inhibitory fan effect operated on the should-be-ignored local letters. Results from both experiments did not support for the inhibition-based fan effect hypothesis. However, in line with Pritchard and Neumann (2004) and Frings et al. (2007), there was evidence for the claim that selective control mechanism are developed much earlier in young children than previously thought.

Selective Attention

Human beings perceive the external environment through different senses. One of the major sensory inputs is through vision. Although viewing the external environment may seem effortless, the complexity of how this is processed in our cognitive system is very complex. “Seeing” requires the activation of selective attention in order to actually focus in on and remember the things that we “saw”. According to the activation-suppression models of attention, the input of visual images (both attended and unattended information) is in parallel and unattended information is quickly inhibited after initial excitation (Pritchard & Neumann, 2004). Selective attention may be used to restrict the flow of information from the sensory memory into the working memory. In order for the image of interest to last longer in our memory, the person would need to actively attend to or think about that selected image for it to proceed into the long term memory. Information that is encoded into the long term memory can then be retrieved back into the working memory for processing or relating to new images (Ericsson & Kintsch, 1995).

An example of how selective attention works would be if a person is looking for a pair of black work pants before going to work, they would first perceive an image of a selection of pants. At this stage all information is analysed in parallel in the sensory memory as mentioned above. Based on the memory of the features of the target black work pants, this person would selectively attend to black coloured ones first which brings this information into working memory. In working memory, the information of the attended black pants would be processed to match or relate to the actual look of the pants that this person is looking for in long term memory. In a case like this, the black work pants act as the main target of attention while the rest of the pants act as distractors that are likely to compete for the same attentional resources.

The ability to switch our attentional focus between competing or spatially distinct events has been extensively studied. According to Bulakowski, Bressler and Whitney (2007), human attentional resources can be shared and freely allocated. For example, when observing the flight path of a flock of birds, there may be differences between the flock's overall direction of motion and any individual bird, yet our visual system can switch our attention between local and global features according to what we want to focus on (Bulakowski et al., 2007). To test this theory, Bulakowski et al.'s (2007) experiment examined the flexibility of the attentional window. Bulakowski et al. (2007) assessed participants' ability to switch focus between a global or grouped motion pattern (larger attentional window) while ignoring a local or individual motion component of the pattern (smaller attentional window) or vice versa. Since global and local motion patterns are usually both important and available in a given scene, the ability to divide and freely allocate our attentional resources to simultaneously attend to both scales of motion is important (Bulakowski et al., 2007).

In Bulakowski et al.'s (2007) experiment, each global image consisted of a pattern of 20 small arrows (four rows of five columns) all moving towards one direction. Each stimulus consisted of two of those global images. For global discriminations, participants were required to judge which of the global images (each aligned with 4 x 5 small arrows) was more upward moving (Bulakowski et al., 2007). For local discriminations, participants were asked to judge the relative motion of a local element (one out of the 20 from each global image), the target local elements are always the two local elements at the bottom of the two global images that were closest to a fixation point. For example, even if the entire pattern (global image) was upward moving, each local image would point and move in a slightly different direction. To test participants' ability to distribute their attentional resources, they were asked to devote their attention toward either global motion or local motion or divide it evenly between the global and local scales. Bulakowski et al.'s (2007) results showed that as participants processed the global and local motion, more attentional resources were allocated towards one scale than another and there was therefore a loss in their precision to discriminate the other motion scale. This suggested to Bulakowski et al. (2007) that the processes for local and global motion compete for common attentional resources (Bulakowski et al., 2007).

Neumann and DeSchepper (1992) agree that both image relevant and irrelevant information is initially processed in parallel, before undergoing further processing. According to these authors, selective attention involves both activation of target information and suppression of distracting, non-target information that is concurrently in competition with targeted information in a display. Therefore, referring to the previous example of the work pants, the mental representation of the other pants that were scanned were then possibly suppressed in the process of cognitively ignoring them, if they were sufficiently competitive with the target black pants.

Negative Priming

Negative priming is a memory effect in which exposure to a previously ignored stimulus results in a subsequent response to that stimulus being slowed and/or less accurate (Pritchard & Neumann, 2004; Mayr & Buchner, 2007). Negative priming tasks typically involve a series of sequential prime and probe couplets in which a target and a distractor are presented together in a prime, followed by a target and a distractor in a probe with the distractor in the preceding prime becoming the target probe. In the Control condition of a negative priming list reading task involving a series of sequential items, the distractor in the preceding trial is not related to the target in the subsequent trial. In the ignored repetition (IR) condition, however, the distractor in the preceding trial will become the target in the subsequent trial, which is the manipulation that typically produces negative priming effects in a series of such trials, in comparison to the Control condition. Negative priming effects are measured by comparing the response times and error rates for the Control condition with the response times and error rates for the IR condition. In list reading negative priming tasks, these Control and IR conditions are represented on separate cards with the stimuli arranged in a column from the top to the bottom of the card.

Negative priming effects were originally discovered by Dalrymple-Alford and Budayr (1966; cited in Tipper & Cranston, 1985) using a list reading task, involving Stroop stimuli. Participants were required to read a list of colour names written in non-corresponding colours (e.g., the word ‘yellow’ written in green ink). Participants were instructed to name the ink colours in which the words were printed in as quickly as possible while ignoring written words. Dalrymple-Alford and Budayr (1966) found that the reaction times of the participants were slower when the ink colours did not correspond to the written colour names. These effects are robust across a range of stimuli types such as Stroop items and novel shapes (Lowe, 1985; Treisman & DeSchepper, 1966). The inhibition-based theory of negative priming holds that inhibition functions to enhance the response to the target in a trial containing a specified target and distractor, in part via the suppression of the activation levels of the response to the distractors (Tipper, 2001). According to Tipper and Cranston (1985), selective attention is not merely a singular process that enables targeted information to be processed further, but also contains the mechanism of actively inhibiting the potentially competing responses of the ignored objects. This mechanism potentially explains how negative priming occurs.

Priming is one of the subclasses of implicit memory as it is an implicit activation of information that is already stored in one’s long-term memory (DeSchepper & Treisman, 1996). DeSchepper and Treisman (1996) used novel, meaningless shapes to test whether unattended shapes would generate mental representations, even when they were previously unfamiliar to the participant. Participants had no consciously retrievable (explicit) memory for the multitude of the unattended novel shapes, yet DeSchepper and Treisman (1996) found that negative priming occurred even when those shapes were unattended and meaningless. This suggested that negative priming does not require explicit memory as participants were unaware of the ignored novel shapes.

Inhibitory Processes in Children

Negative priming is purported to reflect the effect of inhibitory processes acting on the mental representations of ignored information that is concurrently in competition with targeted information (Tipper & Cranston, 1985). While the effect has been widely reported in adults, there have been fewer studies on children (Pritchard & Neumann, 2004). Tipper et al (1989) used the Stroop colour-naming task to test whether children produce comparable negative priming effects to adults. Twenty young adults and 20 children participated in this study and Tipper et al (1989) found that interference was larger in children compared with young adults. This suggested that children may not have efficiently utilized inhibitory processes as their ability to actively inhibit distractors is underdeveloped. Critically, the results also showed that children did not produce significant negative priming effects (Tipper et al, 1989).

This finding was contradicted by a more recent paper by Pritchard and Neumann (2004) where they also tested for negative priming effects in children. The participants were children aged 5 to 12 years and a flanker-type colour-blob task (see

Figure 2) was used. In their experiment, participants were presented with Control and IR cards. Each card contained a column of stimuli consisting of rows of three different-shaped colour blobs tightly interwoven, and participants were required to name the colour of the blob in the middle (the target) of each row starting at the top and ending at the bottom of each card. There were 11 colour blob rows on each card. In contrast to the Control condition, where there was no relationship between the colours from one row to the next, in the IR condition, the target (middle colour blob) in a subsequent trial (row) would always be the same colour as the distractor (flanker) colour blobs in the preceding trial (row). Using this task, Pritchard and Neumann (2004) found intact negative priming effects in children as young as 5 years of age. In contrast to the prevailing view at the time, this demonstrated that children have the ability to attend selectively and that the inhibitory capacity functioning to suppress irrelevant information is intact even in young children.

Pritchard and Neumann (2004) performed the Stroop colour-naming task that Tipper et al (1989) used. The Stroop task usually uses stimuli cards that consist of written colour names printed in a colour that either matches the word (i.e. GREEN printed in the colour green) or does not match the word (i.e. PINK printed in the colour green). In their Control cards, neither the printed colour of the word nor the word of the colour (which acts as a distractor) was related to the subsequent letter. On the other hand, in the IR cards the word of the colour in the previous trial (the letter above the current letter) became the printed colour of the word in the subsequent target. There were 11 colour words arranged in a vertical line on a stimuli card and the participants were required to name the printed colour of each word from top to bottom. This design tested for negative priming similarly to the flanker-type colour blob task as the memory of the “ignored stimuli” interfered with the participant’s reaction time to the current stimuli. In a follow-up study, Pritchard and Neumann (2009) used the same Stoop tasks on children, adolescents, and adults. The authors found that negative priming was intact and comparable between children, adolescents, and adults. This suggests that an inhibitory process is fully developed by early childhood.

Pritchard and Neumann (2009) offered an explanation of the contradiction between their Stroop task and Tipper et al.'s (1989) Stroop task in their paper. They posited that the different outcomes were caused by a minor difference in methodology. Pritchard and Neumann (2009) suggested that although both experiments used Control and IR conditions in which the distractor stimuli were very response competitive with the target stimuli, Tipper et al.'s (1989) experiment also included two additional conditions. The Neutral condition and the Repeated-distractor conditions in Tipper et al.'s (1989) research consisted of distractors that were significantly less response competitive with targets. The Repeated-distractor condition required continuous repetition of one non-target word of a colour that was printed in different colours where the Neutral condition consisted of rows of X's displayed in different target colours. These conditions may have eased selection more broadly for the Stroop task to test for negative priming as children may have felt less incentive to ignore distractors across conditions in this situation (Prichard & Neumann, 2004). A number of studies that tested adult participants using the Repeated-distractor condtion have shown that responses to the target stimuli were facilitated when distractor stimuli were repetitive rather that changing (i.e., Lowe, 1979; Neumann & DeSchepper, 1991; Pomerantz & Garner, 1973; Rabbitt, 1967; Tipper & Cranston, 1985). Pritchard and Neumann (2004) believed that children are more likely to produce negative priming in experimental contexts where there is a high degree of target selection difficulty and where expectation of highly conflicting stimuli are maintained in an experiment-wide manner. The authors concluded that children can produce negative priming comparable to adolescents and young adults if they are tested in a developmentally suited negative priming task.

Frings, Feix, Rothig, Bruser and Junge (2007) compared Tipper et al.'s (1989) study, which concluded that children do not show negative priming, with Pritchard and Neumann's (2004) study which found that children showed intact negative priming. Frings et al. (2007) replicated Pritchard and Neumann's (2004) colour blob task; however, they also added the Repeated-distractor condition for half of the participating children in order to test Prichard and Neumann's (2004) argument. The results showed that even though Frings et al. (2007) did not find evidence that the Repeated-distractor condition had an effect on negative priming, they still found clear evidence for the claim that the negative priming effect for children is comparable to that for adults. These recent findings challenged Tipper et al.'s (1989) beliefs on negative priming in children and therefore, opened a doorway to the many important undiscovered possibilities in the developmental area of inhibition.

Pritchard and Neumann (2011) also used the Stroop negative priming task to test whether increasing the ratio of low conflict condition (Repeated-distractor condition) would eliminate negative priming effects in children. Pritchard and Neumann (2011) used the same experimental design that Pritchard and Neumann used (2004, 2009) for their Stroop negative priming task for Experiment 1. Experiment 1 was to replicate Pritchard and Neumann's (2004, 2009) finding of intact and similar conceptual negative priming effects between children and adults in an experimental context containing 100% high-conflict (Control and IR) conditions (Pritchard & Neumann, 2011). In their Experiment 2, the Stroop task was based on the experimental design used by Tipper et al (1989) that included both low- and high-conflict conditions in equal proportions. Frings et al. (2007) used an experimental context containing 35% low-conflict and 65% high-conflict conditions and found intact negative priming effects in children. However, Pritchard and Neumann (2011) found negative priming intact in adults but not in children using 50% low-conflict Neutral and Repeated-distractor conditions and 50% high-conflict Control and IR conditions. This finding supported Pritchard and Neumann's (2004) prediction that decreases in inhibitory demand in an experiment-wide manner can result in an elimination of children's negative priming effect compared with adults.

Limited Capacity Inhibitory Resources and the Fan Effect

Neumann and DeSchepper's (1992) proposed the working hypothesis that both activation processing and suppression processing were believed to have independent pools of limited capacity resources, one excitatory and one inhibitory. Therefore, in terms of limited capacity inhibitory selective attention processing, when this capacity is divided among processed distractor items, there is a systematic diminution of available inhibitory resource with each additional distractor (Neumann & DeSchepper, 1992; see also Neumann, Cherau, Hood & Steinnagel, 1993). In the context of a negative priming manipulation, the to-be-ignored distractor items would not be treated passively through the removal of attentional resource but rather actively suppressed as a by-product of selecting the target in a competitively taxing selective attentional situation. Because the inhibitory mechanism is a limited capacity resource in this model, as the number of to-be-ignored distractors increases, the degree to which each one is suppressed attenuates. For example, in comparison to a targeted pair of black pants next to one pair of blue pants, if there are two pairs of distractor pants in competition with the target black pants, less inhibition would be attached to each one - thus producing less negative priming if one of them becomes the subsequent target. Neumann and DeSchepper (1992) referred to this as an “inhibition-based fan effect”. Empirical support for the suppression process in selective attention and the inhibition-based fan effect comes from research using the negative priming paradigm.

Neumann and DeSchepper (1992) proposed that the selective inhibitory attentional mechanism that underpins negative priming involves tagging “object files” with the status of “unwanted memories” for the ignored distractor(s) on a given trial (see Figure 1). As discussed above this process would slow participants’ response and/or the response would be less accurate if the distractors appeared as a target in a subsequent trial. Neumann and DeSchepper (1992; see also Neumann et al. 1993), using target and distractor letter stimuli, showed that the time it took their participants to name a target letter was longer for stimuli that had been a distractor in the prime trial. More critically, however, Neumann and DeSchepper (1992; Neumann et al. 1993) also found that negative priming effects attenuated as the number of distractors in a prime trial increased.

The inhibition-based fan effects observed by Neumann and DeSchepper (1992) and Neumann et al. (1993) support a late selection model of selective attention which holds that visual target and distractor objects are processed in parallel. This model maintains that to enable the efficient selection of target items, unwanted objects would be actively suppressed, while target objects would remain activated for further processing (e.g., Tipper, 1985). From Neumann and DeSchepper’s extension of this perspective, inhibition-based fan effects should occur for unwanted distractors if inhibition were a limited capacity attentional resource. Consistent with what they predicted, the magnitude of negative priming declined systematically as the number of distractors increased from 1 to 2 to 3 in a list reading task. Moreover, in a prime –

probe couplet version of a similar letter naming task, the number of distractor letters was manipulated only in the prime display, but they obtained the same pattern of results despite the probe stimulus only containing one distractor letter (Neumann et al. 1993). Again, there was a systematic attenuation of negative priming to the probe target item in the IR condition, relative to the Control condition, as more distractor letters were added to the prime display.

An unpublished PhD thesis by Andrews (2010) claimed to further examine whether negative priming effects would attenuate when multiple distractors shared a common feature. In the first experiment in which she attempted to test the inhibition-based fan effect idea, Andrews (2010) used a letter task that consisted of 1, 2 or 3 distractors where each distractor overlapped a different corner of the target letter and all colours of the distractor letter stimuli were chosen randomly from eight possible colours. The two conditions, the Repeated condition and the Control condition, were identical except the probe target was presented in the same colour as one of the prime distractors on the repeated trials. In comparison, the probe target in the Control condition was presented in a different colour from the distractor. Participants were asked to identify whether the letter was an X or a Z for the prime trials and an N or an M for the probe trial by pressing the corresponding keys on a computer keypad. Eighteen adults participated in Experiment 1 and the results showed negative priming effects did attenuate as the number of distractors increased.

Andrews’ (2010) results were consistent with Neumann and DeSchepper’s (1992) findings; however, Andrews questioned whether the result of this effect was due to the capacity limited by the number of items as claimed by Neumann and DeSchepper (1992) or whether it was actually due to the number of item types. In Andrews' (2010) Experiment 2, the displays of the trials still contained multiple distractors; however, in contrast to Experiment 1, all distractor letters were presented in the same colour. The results showed that for the 23 adults that participated in Experiment 2, negative priming effects remained across all conditions even when selection involved up to four distractor items. Andrews (2010) concluded that the attenuation of negative priming effects was caused by feature-based cost effects rather than the inhibition-based fan effect.

There might, however, be a potential flaw in the aforementioned conclusion. By changing all the distractors to the same colour, negative priming effects may still occur, but not the fan effect. To clarify, in Andrews' (2010) experiment, the participants' main source of interference was actually the colour of the letters. This is because Andrews (2010) observed negative priming effects when the probe target was presented in the same colour as one of the prime distractors on the repeated trials. Critically, by changing all the distractors into the same colour there was only one feature colour (i.e. blue) to inhibit. The non-target distractor was a singular feature, in this case, whereas to create a condition susceptible to the inhibition-based fan effect notion, there must be more than one distractor concept in order for the diffusion of inhibition to take place. Thus, the experiment only tested for negative priming effects not the fan effect as there were no multiple distractors to inhibit that would compete for the limited capacity of the inhibition mechanism. To conclude, on the basis of Andrews' findings, the claim that there was an overlap between the enduring inhibitory processes underlying negative priming and the feature-based cost effects is questionable and the status of the inhibition-based fan effect idea is still intact.

To date, no studies have been conducted on inhibition-based fan effects in children, or how these effects might vary as a function of age. A primary aim of the present investigation is to determine if human development can affect the inhibition-based fan effect. Pritchard and Neumann (2004) have shown that children are capable of producing intact inhibitory effects in negative priming tasks using the colour-blob flanker task and more recently provided evidence for equivalent negative priming effects in children, adolescents, and adults using this task (see Pritchard & Neumann, 2009). An equally important question is whether age would have an effect on the inhibition-based fan effect.

Aims of Current Experiments

In the current Experiment 1, Pritchard and Neumann's (2004) colour-blob flanker task was used to test children and young adults. The critical focus was to include a fan manipulation to assess whether inhibition affecting distractors diffused as the number of different coloured distractor blobs increased, and to determine if inhibition-based fan effects differed by age. In the fan manipulation (i.e., one vs. two distractors), the distractor flanker blobs were presented in different colours in the "2-distractors" condition, instead of a single colour as in the "1-distractor" condition. This was designed to test whether having more than one distractor colour would decrease negative priming effects and thereby provide evidence for an inhibition-based fan effect. To date, the extent to which inhibition-based fan effects replicate with stimuli other than letters, or might differ by age, is completely unknown. The hypothesis of this experiment was that the fan manipulation would show an inhibition-based fan effect as evidenced by reduced negative priming effects in the 2-distractor condition, relative to the 1-distractor condition.

A further aim of the present study was to extend findings of the inhibition-based fan effect to another stimulus type. To extend such an effect to other stimuli, and to evaluate the degree to which limited capacity inhibition spreads across distractors, a second experiment of a local-global letter task was conducted that included one, two, or three local letter distractor conditions. Accordingly, in this second experiment, there was an extension to the test of the inhibition-based fan effect by including 1, 2, or 3 distractors comprising the target global letter. As in the previous experiment, the least fan (most inhibition) should be applicable in the condition where there was just one local distractor letter comprising the global letter, with greater fan (less inhibition) where there were two different local distractor letters. The greatest fan (least inhibition) should be applicable to the distractors in the three different distractor letters condition. Again, the predicted outcome was that the most negative priming should be observed in the one distractor letter condition, with diminishing negative priming as the number of different local distractor letters increases (1-distractor vs. 2-distractors vs. 3-distractors, respectively).

Another reason that the local-global letter task was used, in addition to the colour-blob flanker task, was that it can control for a possible confounding factor inherent in the flanker task whereby participants only look at one side of each stimulus row, which means they might only perceive one distractor colour, even when there are two different distractor colours. If participants were able to do that, they would potentially produce what could be interpreted as an inhibition-based fan effect, because the previous distractor colour would only become the subsequent target colour on about half as many trials in the IR condition when there are two distractor colours. This could produce less negative priming than the one distractor colour IR condition, because in that condition the distractor colour consistently becomes the subsequent target colour. Because the local letters comprise the shape of the target global letter in the local-global letter task, this possible artefact of selective looking is eliminated.

In summary, the research aims and hypotheses for this study are as follows:

1. To examine inhibitory selective attention mechanisms in children and adults using both a flanker type colour-blob task, and local-global letter task.

2. To determine whether children and adults show an inhibition-based fan effect in the colour blob and local-global letter task. In both cases, this would be evidenced by an attenuated negative priming effects as a function of increasing the number of distractors to be ignored.

3. To test for potential interactions between age, stimulus type, and number of to-be-ignored distractors in the magnitude of the inhibition-based fan effect.

It is hypothesized, that the more distractors there are, the more the negative priming effects should diminish in both selective attention tasks (i.e., inhibition-based fan effects should be observed). This inhibition-based fan effect would be evidenced by a decrease in the magnitude of the negative priming as a function of increasing the number of distractors competing with a target in a visual display; and the consequence of that dispersion of inhibition, should one of those distractors become the subsequent target stimulus. In addition, children and adults should produce comparable inhibition-based fan effects, because there is no apparent reason to suggest that the core inhibitory mechanism underpinning negative priming operates any differently in children than in adults.

In summary and to be more concrete regarding the present two experiments, the main hypothesis is that adding one additional unique distractor would reduce the magnitude of negative priming effects compared with having just one distractor (Experiment 1). Moreover, , by adding two additional unique distractors, this should reduce the magnitude of negative priming even more than when there are only 2 distractors (Experiment 2).

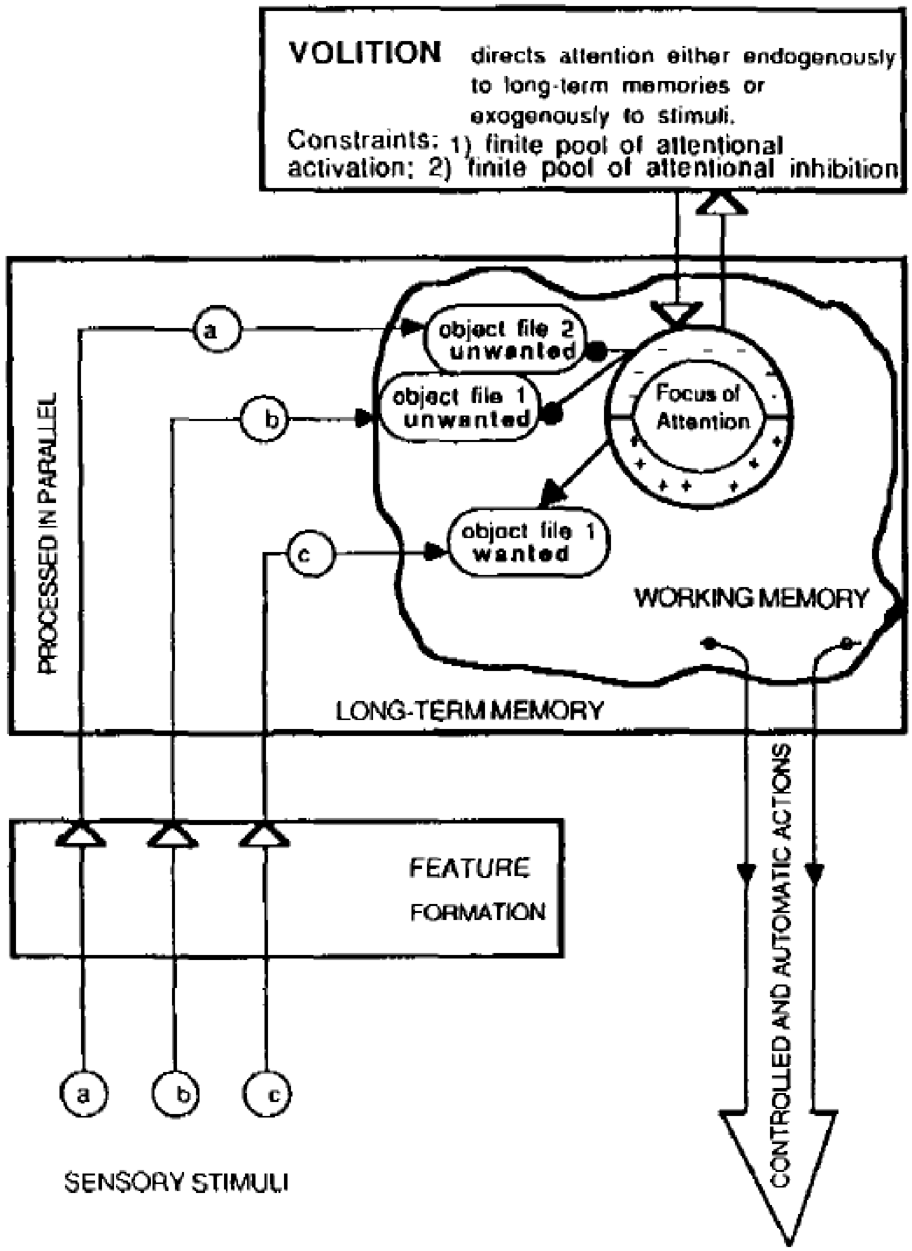

Figure 1. Neumann and DeSchepper's (1992) model of selective attention.

Experiment 1

Experiment 1 was an attempted replication and extension of an experiment by Pritchard and Neumann (2004) investigating negative priming effects in adults and children. Stimuli consist of a central target colour blob flanked on either side by coloured distractor blobs. With this configuration, Pritchard and Neumann (2004) reported a strong negative priming effect. Moreover, children produced adult-like negative priming effects when distractor competition was held constant in the experimental context. In Experiment 1, a condition was added to expand on Pritchard and Neumann's (2004) task. The additional condition was designed to examine the role of an inhibition-based fan effect by using distractors with different colours on either side of the central target (see Figure 2). By using two different distractor colours the negative priming effect should attenuate, if the prediction derived from the inhibition-based fan effect were to hold up.

Method

Participants

Sixty students from the University of Canterbury took parst either for course credits or a $10 mall voucher. Their median age was 20 years (ranging from 17 to 42 years). Fifty-two Primary School children took part for a certificate and a page of stickers. Their median age was 7 years and 7 months (ranging from six years and nine months to eight years and three months). All participants self-reported having normal, or corrected to normal vision, including normal colour vision.

Stimuli and Apparatus

The experiment was conducted using stimuli cards and a stopwatch. All stimuli were shown on legal sized (216 × 356mm) pale yellow card. There were 24 cards in total with each condition containing six cards and there were four conditions in total (Control 1 (C1), Control 2 (C2), Ignored Repetition 1 (IR1) and Ignored Repetition 2 (IR2)). Each card comprised 11 unique sets of three slightly different-shaped colour blobs that were presented in a list format on the card. A single colour blob measured approximately 2.0 cm in height and 2.0 cm in width. Sets of three colour blobs were presented as rows spread equally across on a legal sized page on the card. These sets formed a vertical column, and every card had rows of colour blobs that were staggered to appear slightly to the left or right of each other. Shifting the blob sets was intended to help reduce participants noticing the relationships in the IR conditions. Visual distances between individual blob rows were the same for both IR and control cards and also for each colour blob set. The centre blob in each colour blob set functioned as the target, and the two outer colour blobs functioned as distractors. The distractor colour blobs were either identical in colour for the C1 and the IR1 conditions or comprised two different colours for the C2 and the IR2 conditions (see Figure 2). In the C1 condition, the distractor colour blobs were the same colour for each set on each card and the colour of the target colour blobs in the probe (next) trial were not related to any colours in the preceding trial. In contrast, in the IR1 condition one of the outer distractor colour blobs from the previous trial was always the next target colour blob. To gauge the inhibition-based fan effect, two different flanker colour blobs were used. In the C2 condition, none of the colours used on the current trial were related to colours used on the next trial. By contrast, in the IR2 condition, one of the distractor colour blobs from a previous trial was always the target colour on the subsequent trial.

Using the same concept as the original work by Prichard and Neumann (2004), the three colour blobs in each set were arranged close together with intermeshed contours to maximize selection difficulty. In the present experiment, the ratio of the flanker target colour blobs and their proportions remained constant in order to minimize bias in the IR2 condition. This was achieved by utilizing a design program. This was to avoid participants seeing more of one distractor than the other by looking at one side of the colour blob sets. Colours for the blobs were black, red, blue, pink, green, brown, purple, grey, yellow, orange and white. For all conditions, the first two colour blob sets were always unrelated in order to reduce the potential saliency of the IR conditions.

Prior to the experiment, four additional control cards were administered to participants as practice trials. The practice trials were not included in the results. The four practice cards were the same as the Control conditions (C1 and C2) to deter participants' from noticing any systematic relationships among colours from one row to the next during the experiment proper.

Participants in each age group began the experiment with a card representing one of the four conditions, so that all four conditions were equally represented. The conditions were counterbalanced so that the condition cards regularly alternated between control and IR conditions. A card from one of the four conditions was presented followed by a card from another of the four conditions, etc., in pseudo-random fashion. For example, if a person began with an IR2 card, the next card would have to be a Control card, but it could either be a C1 or a C2 card. The following card would have to be an IR card, but since an IR2 card had already been used, it would have to be an IR1 card. The next set of four conditions would need to start with a Control card (to maintain the regular alternation), but it could be either a C1 or a C2 card. There are several important reasons for doing the counterbalancing and pseudo-randomization in this way. It is known from the previous work by Pritchard and Neumann that participants are much faster to name colours on cards in the second five minutes of doing this task than the first five minutes. Therefore, in order to avoid practice artefacts it is very important to have all conditions encountered in similar periods of time throughout the experiment. Regular alternation between Control and IR conditions is important because if 2 or 3 cards in a row were to involve IR conditions, it is more likely that some participants may notice that the distractor colour from one trial becomes the target in the next. Of course, if any participants notice that relationship they can predict the upcoming target in the IR condition and would therefore likely produce positive priming, instead of negative priming effects. It is also better if participants cannot predict whether the upcoming card will have one distractor colour, or two, to help avoid any anticipatory strategies.

Procedure

University students were tested individually in a quiet room in one session lasting approximately 25 minutes together with Experiment 2. For primary school students, Experiment 1 was tested in one session for 15 minutes and they were allowed 10 minutes break before going on to Experiment 2.

Participants were given verbal instructions for the colour blob task. At the beginning of each session, participants were asked to identify the colours on a colour familiarization sheet. This card had 11 coloured squares printed in black, red, blue, pink, green, brown, purple, grey, yellow, orange and white. Participants were instructed to name each colour as a test for both colour vision impairment and familiarity with the colour names. The second card was exactly the same but with the common name written beside it to confirm the naming of those colours.

After the colour familiarization procedure, the participants were then instructed to quickly name the colour of each middle blob as quickly and accurately as possible while ignoring the other two outer colour blobs on each card before starting their practice trials. The order of naming was from top to bottom of each card. Before each participant started the task, the experimenter emphasized that when an error was made, participants should not stop, but continue to complete colour naming for the card. Each participant started with four controlled practice cards (two cards that looked like C1 cards and two cards that looked like C2 cards). Participants were told by the experimenter that only the first three cards were the practice cards. Therefore, the last practice card was treated by the participant as the first experimental card.

The practice cards were then followed by 24 test cards (six C1 condition, six IR1 condition, six C2 condition and six IR2 condition in total). For each card, the experimenter said “Ready” as a warning, and on the word “Go,” a blank card covering the test card was removed and the stopwatch started. The timer was stopped when the participant had named the last target colour blob in the column displayed on the card. The number of errors was then recorded beside each card number as well as the time taken to complete each card.

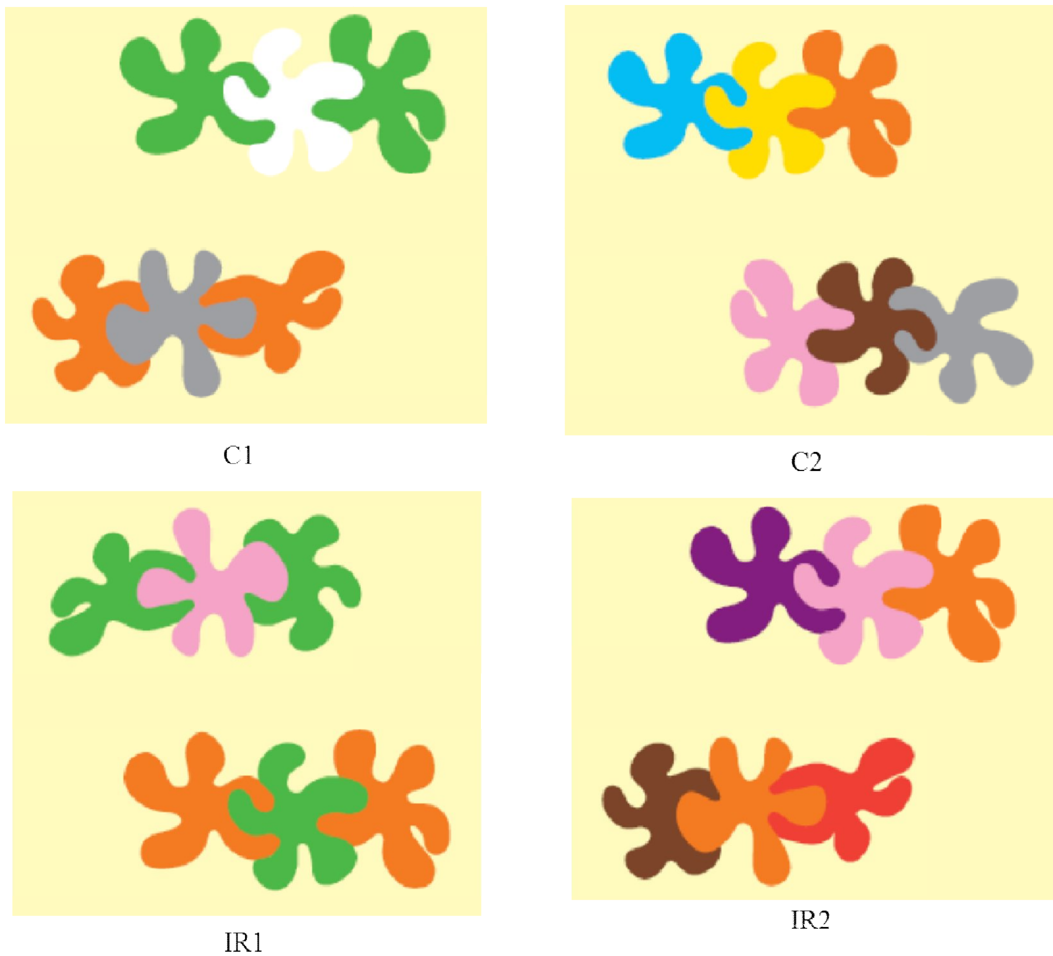

Figure 2. Example of C1, C2, IR1 and IR2 trials in Experiment 1. Participants were asked to name the colour of the central blob in each row while ignoring the outer colour blobs.

Results

Adult participants that scored extreme scores for trials taking longer than 10 seconds or scored more than 5 errors within a condition were excluded from the data. Child participants that scored longer than 25 seconds or scored more than 5 errors within a condition were excluded from the data. Nine out of 60 adults were excluded from the data. Twelve out of 52 children were excluded from the data.

For each participant, a mean reaction time in seconds per card was computed from six cards representing C1, six cards representing C2, six cards representing IR1 and 6 cards representing IR2. Mean reaction times, percentages of errors and the magnitude of negative priming for both reaction times and error percentages for all four conditions for adults and children are shown in Table 1. The magnitude of negative priming and error percentage were calculated by IR minus Control means for relevant groups in Figure 3.

A three-way mixed-design analysis of variance (ANOVA) was carried out on the mean reaction times. The between-subjects factor was age group (children vs adults), and the within-subject factors were priming condition (Control vs. IR) and number of distractors (1 vs. 2 distractor colour blobs). The between-subjects factor of age group was significant, $F(1, 87) = 411.41$, $p < .001$ with children responding significantly more slowly compared with adults. The first within-subject factor of priming condition (Control vs IR) was significant, F (1, 87) = 26.29, $P < .001$. Participants responded slower on IR trials than on Control trials. The second within-subject factor which was the number of distractors (1 vs. 2 distractor colour blobs) was also significant, $F(1,87) = 63.55$, $p < .001$. However, as can be seen in Figure 3, participants responded more slowly on trials that contained two distractor colour blobs. Finally, the interaction between priming condition and age group was significant, $F(1, 87) = 15.5$, $p < .001$. Age was related to the overall processing speed, whereas the negative priming effects were not similar across the age groups. Bonferroni post hoc tests revealed that adults produced less negative priming than children as these post hoc tests were not significant for the adults p > 1.0.

The interaction between the number of distractor colours and age group was also significant F (1, 87) = 9.44, p <.05, indicating that the interference of the number of distractor colours was not similar across the age groups. However, a Bonferroni post hoc test showed a significant difference when there was one distractor colour than when there were two distractor colours for adults even though the results were not as low as the children's results ($p > 0.01$). Using a follow-up analysis which analysed only the first half of the raw data for all conditions, the interaction between the number of distractor colours and age group turned out not to be significant F (1,87) = 1.84, $p > 0.18$. This supported the Bonferroni post hoc tests and the effect for interference on the number of distractor colours was comparable across the age groups tested. Lastly, the interaction between the number of distractor colours and priming condition was also significant F (1, 87) = 4.96, $p <.05$. This means that the overall effect of negative priming was not similar across the different number of distractor colours. Bonferroni post hoc tests revealed that in the one distractor colour condition there was no significant negative priming ($p > 0.5$). The three way interaction between the number of distractors, age group and priming condition was not significant F (1, 87) = 0.9, $p >.05$, this means that none of the three individual variables is dependent on the other ones.

Similar analyses were conducted for error scores. The between-subjects factor of age group (adults vs. children) was significant, F (1, 87) = 4.72, $p < 0.05$ where children made more errors compared with adults. However, the within-subject factor of priming condition (Control vs. IR) was not significant F (1, 87) = 1.58, $p > 0.21$. The priming condition only became significant F (1, 87) = 11.59, $p < 0.01$ after using only the first half of the raw data for all conditions. In that case, participants made more errors on IR trials than on Control trials. The other within-subject factor of number of distractor colours was not significant F (1, 87) = 0.0005, $p > 0.98$ even when only the first half of the raw data were used for all conditions. The number of distractor colours did not seem to have an effect on the number of errors made by the participants. Finally, there was no significant interaction between priming condition and age group, F (1, 87) = 0.43, $p > 0.51$. Furthermore, there was also no significant interaction between the number of distractors and age, F (1, 87) = 0.39, $p > 0.31$ and priming condition and the number of distractor colours, F (1, 87) = 0.06, $p > 0.8$. Finally, the three way interaction between the number of distractor colours, age group and priming condition for error rates was not significant F (1, 87) = 0.32, $p > .05$ Thus, the error results corroborated the reaction time results because there was no indication of a speed-accuracy trade-off.

Table 1

Mean Response Time (in Seconds) and Standard Deviation per Card, Percentage of Errors and the Magnitude of NP and Error Percentage for Each Age Group as a Function of Priming Condition and the Number of Distractors in Experiment 1.

	Children		Adults	
	1 distractor	2 distractors	1 distractor	2 distractors
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
Control raw score (seconds)	11.56 (2.41)	12.17 (2.46)	5.30 (0.75)	5.28 (0.77)
IR raw score (Seconds)	12.07 (2.07)	13.30 (2.89)	5.58 (0.81)	5.81 (0.81)
Control error rate (%)	0.97	0.91	0.59	0.56
IR error rate (%)	1.13	1.04	0.74	0.92
Magnitude of NP (Seconds)	0.23	1.12	-0.02	0.23
Magnitude for error (%)	0.12	0.04	0.15	0.36

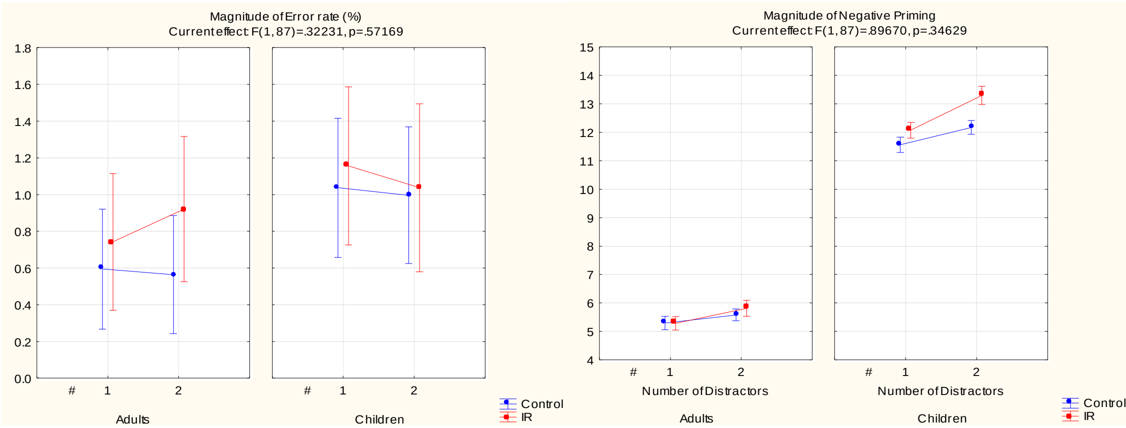

Figure 3. Age group as a function of priming and number of distractors. Mean reaction times (on right) and mean error percentages (on left). Error bars indicate standard errors of mean.

Discussion

Experiment 1 yielded a few interesting results concerning the interactions between age and inhibitory selective attention mechanisms. Firstly, the most important finding is that the results for Experiment 1 support Pritchard and Neumann (2004) and Frings et al. (2007) for an intact inhibitory mechanism of visual selective attention in children. Children do produce negative priming and these findings contradict those reported by Tipper et al. (1989). The interaction effect between priming condition and age group was also similar to the result reported by Pritchard and Neumann (2009) that the flanker stimuli used in Experiment 1 produced significantly greater negative priming in children than adults and that negative priming actually failed to reach significance in adults. Pritchard and Neumann (2009) were able to find support for negative priming being intact and comparable between children and adults after using transformed reaction time data. To overcome the possible bias in Experiment 1, two additional analyses were used. The first analysis was that all the raw data were divided into first half and second half. This separation analysis helps to identify whether there was a practice effect due to Experiment 1 containing twice as many stimuli compared with Prichard and Neumann (2004). A log transformation analysis was also performed as Pritchard and Neumann (2009) used s log transformation to correct for the Age group x priming condition interaction. However, both analyses showed similar results and the interaction between age group and priming condition was still significant.

The results contradicted the main hypothesis, of an inhibition-based fan effect, in that the magnitude of negative priming is larger for two distractor colours compared with one distractor colour for children. The magnitude of negative priming for adults showed that for one distractor colour there was a slight positive priming effect whereas for two distractor colours, the results were back to negative priming. This would mean that the results indicate no inhibition-based fan effect in both children and adults using the colour blob task. In this flanker type stimuli task, Prichard and Neumann (2004) found intact conceptual negative priming in children using just one distractor flanker colour blobs. It is interesting that the results for Experiment 1 actually show very little negative priming effect for the one distractor conditions. It is important to understand why negative priming effects were small in Experiment 1 as this can affect the overall test for an inhibition-based fan effect. It is possible that for the two distractor colours condition, reaction times were relatively long only when compared with Experiment 1's one distractor colour condition.

To gain more confidence in these results and the conclusions derived from them, it is important to find results that would support these conclusions from other paradigms. In the next experiment, the main purpose was to investigate negative priming effects and inhibition-based fan effects in both adults and children using a different task. Experiment 2 was designed to eliminate the possible bias in the colour blob task and to thus determine the reliability of the outcome of Experiment 1.

Experiment 2

In the second study, the inhibition-based fan effect and negative priming effects were further tested using Navon's (1977) local-global letter task in both children and adults. This task involved a large global letter composed of arrangements of many small local letters which acted as distractors. However, building on the original local-global letter task, Experiment 2 included two additional trials. The first trial had two different local letters for each global letter, but the second trial had three different local letters that made up each global letter. Experiment 2 aims to help assess the reliability of Experiment 1 using a different stimuli type task and to test the inhibition-based fan effect in a task that has not been used before.

Method

Participants

The same 60 university adults and 52 primary children who participated in Experiment 1 were used for Experiment 2.

Stimuli and Apparatus

The experiment was conducted using stimuli cards and a stopwatch. Stimuli were shown on a legal sized (216 × 356mm) white card. The global letter was made up of many local letters all printed in black Arial font (see Figure 4). Twenty consonants were used for both global and local letters. The reason for not using vowels in this experiment was to prevent a potential Stroop-like conflict as it is possible that words would be spelled out. There were 36 cards in total, each condition contained six cards and there were six conditions in total (C1, C2, C3, IR1, IR2 and IR3). Each card comprised 11 global letters which were made up of one, two or three local letters that were presented in a list format on the card. A single global letter was measured closest to the approximation of 1.8cm in width and 2.3 cm in height and a local letter was 0.4

cm in width and 0.4 cm in height. The global letters were presented equally spread on a legal sized page in a vertical column on the card. Every card had 11 global letters that were staggered to appear slightly to the left or right. Shifting the global letters this way was intended to help reduce participants noticing the relationships in the IR conditions. Visual distances between individual global letters were the same for both the IR and the Control cards. The global letters functioned as the target, and the local letters functioned as distractors. There was one local letter for C1 and IR1, two different local letters for C2 and IR2 and three different local letters for C3 and IR3 for each of the global letter (see Figure 4).

In the C1 condition, the distractor local letters were the same for each global letter. The global letter in the probe trial was not related to any local letters in the preceding trial. In contrast, in the IR1 condition, the local letters from the previous trial were always the next target which was the following global letter. To gauge the inhibition-based fan effect, two and three distractor local letters were used. In the C2 condition, none of the letters used on the current trial (prime) were related to the letters used on the next trial (probe). In contrast, in the IR2 condition, there was an equal potential that one of the distractor local letters on a previous trial would always become the global letter in the subsequent trial. To see if there was a possibility of further diffusion of inhibition, C3 and IR3 conditions were included. In C3 conditions, all global letters consisted of three different local letters and none of the letters used on the prime trial were related to the letters used on the probe trial. However, in the IR3 condition there was an equal potential for any of the three local letters on the prime trial to become the global letter on the probe trial. For all conditions, the first two local-global letters were always unrelated in order to reduce the potential saliency of the IR conditions.

Six additional control cards were administered to participants as practice trials prior to the experiment which were not accounted for in the results. The six practice cards were all akin to the Control conditions (two each) to help avoid participants' noticing any systematic relationship among letters from one row to the next during the experiment. The stopwatch was used to record the time taken to complete naming the global letters for each card and error scores were also recorded by the experimenter.

Participants in each age group began the experiment with a card representing one of the six conditions, so that all six conditions were equally represented. The conditions were counterbalanced so that cards were presented in regular alternation between the Control and the IR conditions, and cycled through an exemplar of each of the six conditions, followed by a different exemplar of the six conditions, etc., in pseudo-random fashion. For example, if a person begins with an IR2 card, the next card would have to be a Control card, but it could either be a C1, C2 or a C3 card. The following card would have to be an IR card, but since an IR2 card has already been used, it would have to be either an IR1 card or an IR3 card. The next set of six conditions would need to start with a Control card (to maintain the regular alternation), but it could be a C1, C2 or a C3 card. There are several important reasons for doing the counterbalancing and pseudo-randomization in this way. The main reason for doing so was to avoid practice artefacts, therefore, it was very important to have all conditions encountered in similar periods of time throughout the experiment. Regular alternation between Control and IR conditions was important because if 2 or 3 cards in a row were to involve IR conditions, it is more likely that some participants may have noticed the relationship between global and local letters. Of course, if any participants notice that relationship, they can predict the upcoming target in the IR condition and would therefore probably produce positive priming, instead of negative priming effects. It is also better if participants cannot predict whether the upcoming card will have one, two, or three local letters to help avoid any anticipatory strategies.

Procedure

Experiment 1 and 2 were conducted on University students who were tested individually in a quiet room in one session lasting approximately 25 minutes together. For primary school students, Experiment 1 was tested in one session for 15 minutes and they were allowed 10 minutes break before going on to Experiment 2. Participants were given verbal instructions for the local-global letter task. At the beginning of each session, participants were instructed to quickly name the global letter as quickly and accurately as possible while ignoring the other local letters on each card before starting their practice trials. The order of the naming was from top to bottom of each card. Before participants started the task, the experimenter emphasized that when an error was made, participants should not stop but continue to complete naming the global letter for the card. Each participant started with six control condition practice cards, two from each of the control conditions. Participants were told by the experimenter that only the first five cards were the practice cards. Therefore, the last practice card was treated by the participant as the first experimental card. The practice cards were then followed by 36 test cards (six cards for all six conditions). For each card, the experimenter said “Ready” as a warning, and on the word “Go,” a blank card covering the test card was removed and the stopwatch started. The timer was stopped when the participant had named the last global letter in the column displayed on the card. The number of errors were recorded beside each card number as well as the time taken to complete each card.

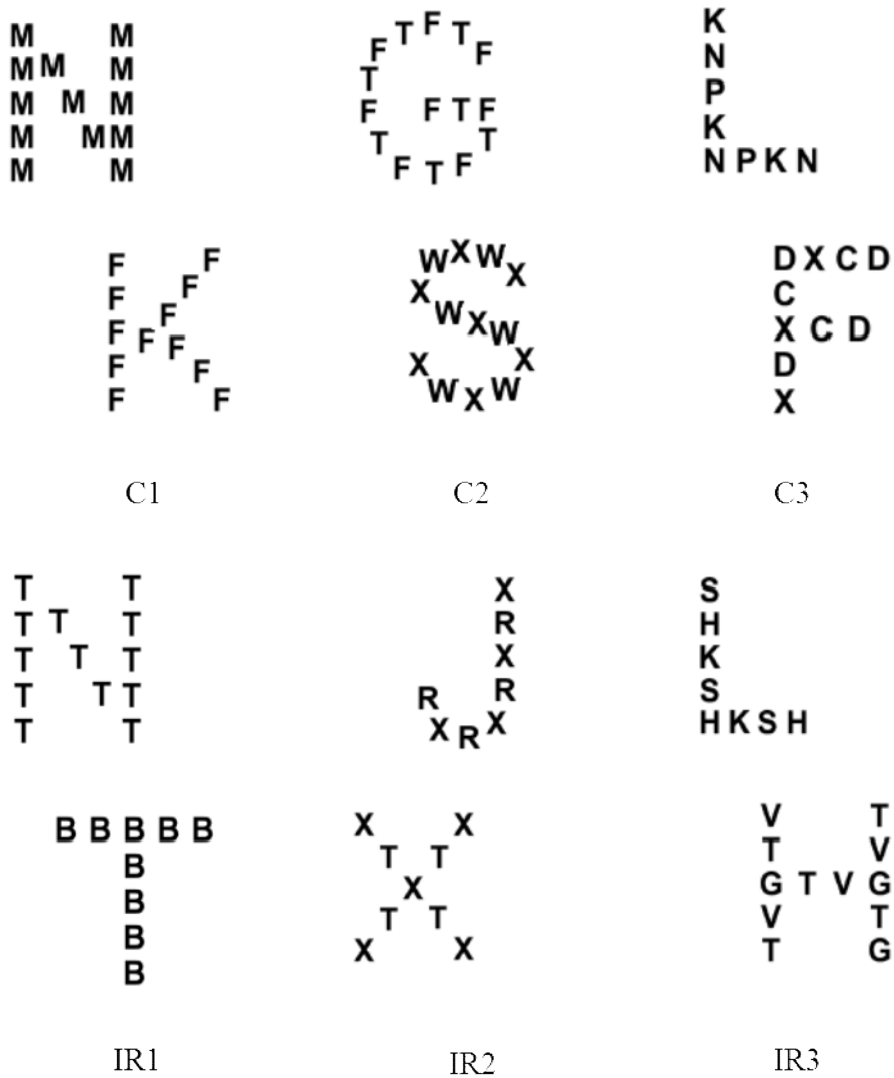

Figure 4. Example of C1, C2, C3, IR1, IR2 and IR3 trials in Experiment 2. Participants were asked to name the global (big) letters while ignoring the local (small) letters.

Results

Adult participants that scored extreme scores for trials taking longer than 10 seconds or scored more than 5 errors within a condition were excluded from the data. Child participants that scored longer than 25 seconds or scored more than 5 errors within a condition were excluded from the data. The people that were excluded from Experiment 1 were also excluded from Experiment 2.

For each participant, a mean reaction time in seconds per card was computed from six cards representing C1, six cards representing C2, six cards representing C3, six cards representing IR1, 6 cards representing IR2 and six cards representing IR3. Mean reaction times, percentages of errors and the magnitude of negative priming for both reaction times and error percentages for all six conditions for adults and children are shown in Table 2. The magnitude of negative priming and error percentage were calculated by IR minus Control means for relevant groups in Figure 5.

A three-way mixed-design analysis of variance (ANOVA) was carried out on the mean reaction times. The between-subjects factor was age group (children vs adults), and the within-subject factors were priming condition (Control vs. IR) and the number of distractors (1, 2 or 3 distractor letters). The between-subjects factor of age group was significant, F (1, 87) = 573.44, p < .01, indicating that children responded more slowly compared with adults. The first within-subject factor of priming condition (Control vs IR) was not significant, F (1, 87) = 0.04, P > 0.05. Participants did not respond significantly differently between IR trials and Control trials. However, after using only the first half of the data, a negative priming effect was marginally significant for the overall data, F (1, 87) = 3.01, p = .086. The second within-subject factor which was the number of distractors (1, 2 or 3 distractor letters) was significant, F (2, 174) = 36.41, p < 0.01. As shown in Figure 5, tasks that contained two distractor letters were the hardest compared with tasks that only contained one or three distractors. Participants responded fastest in tasks that had only one distractor letter.

The interaction between priming condition and age group was not significant, F (1, 87) = 0.02, p > 0.88. Thus, age was not related to the overall processing speed and negative priming effects were similar across the age groups. However, the interaction between the number of distractor letters and age group was significant F (2, 174) =

11.22, $p < 0.01$. This means that the interference effect of increasing the number of distractors was not similar across the age groups. A Bonferroni post hoc test showed that there were no significant differences for the adults between the different numbers of distractor letters (all *p*s > 0.05). Furthermore, children responded slightly faster on trials that contained three distractor letters compared with trials that contained two distractor letters. A Bonferroni post hoc test showed that this difference is also not significant ($p > 0.05$). The last interaction effect of priming condition and the number of distractor letters was also significant F (2, 174) = 10.12, $p < 0.01$, indicating that the overall effect of negative priming was not similar across different numbers of distractors. A Bonferroni post hoc test showed that there was no significant difference between two distractor letters trials and three distractor trials in the Control conditions ($p > 0.05$). Furthermore, in the IR conditions, there was also no significant difference between two distractor letter trials and three distractor trials and participants' response times were similar for one distractor trials and three distractor trials ($p > 0.05$).

The three way interaction between the number of distractors, age group and priming condition was also significant F (2, 174) = 7.72, $p < 0.01$, this means that at least one of the three individual variables is dependent on the other ones.

Similar analyses were conducted for error scores. The between-subjects factor of age group (adults vs. children) was significant F (1, 87) = 19.96, $p < 0.01$, where children made more errors compared with adults. However, the within-subject factor of priming condition (Control vs. IR) was not significant F (1, 87) = 2.1, $p > 0.15$. The number of errors for both IR and Control trials were similar. The other within-subject factor of number of distractor letters was significant F (1, 87) = 3.81, $p < 0.05$. Overall, participants made more errors as the number of distractor letters decreased. Finally, there were no significant interactions between priming conditions and age group, F (1, 87) = 3.66, $p = 0.06$, or the number of distractor letters and age, F (1, 87) = 0.89, $p > 0.05$. In addition, there are no significant interactions between priming condition and the number of distractors F (2, 174) = 1.11, $p > 0.05$, and no significant three way interactions either F (2, 174) = .85, $p > 0.44$. Thus, there was no indication of a speed-accuracy trade-off.

Table 2

Mean Response Time (in Seconds) and Standard Deviation per Card, Percentage of Errors and the Magnitude of NP and Error Percentage for Each Age Group as a Function of Priming Condition and the Number of Distractors in Experiment 2

	Children			Adults		
	1 distractor *M (SD)*	2 distractors *M (SD)*	3 distractors *M (SD)*	1 distractor *M (SD)*	2 distractors *M (SD)*	3 distractors *M (SD)*
Control raw score (Seconds)	9.35 (1.68)	10.60 (1.92)	10.67 (1.96)	4.09 (0.63)	4.44 (0.67)	4.38 (0.63)
IR raw score (Seconds)	9.99 (1.93)	10.57 (1.79)	10.12 (1.89)	4.18 (0.65)	4.32 (0.61)	4.40 (0.58)
Control error rate (%)	1.65%	1.16%	1.03%	0.74%	0.62%	0.48%
IR error rate (%)	1.10%	1.09%	0.85%	0.77%	0.59%	0.62%
Magnitude of NP (Seconds)	0.64	-0.04	-0.55	0.10	-0.11	0.06
Magnitude of error (%)	-0.52	-0.18	-0.08	0.04	-0.02	0.10

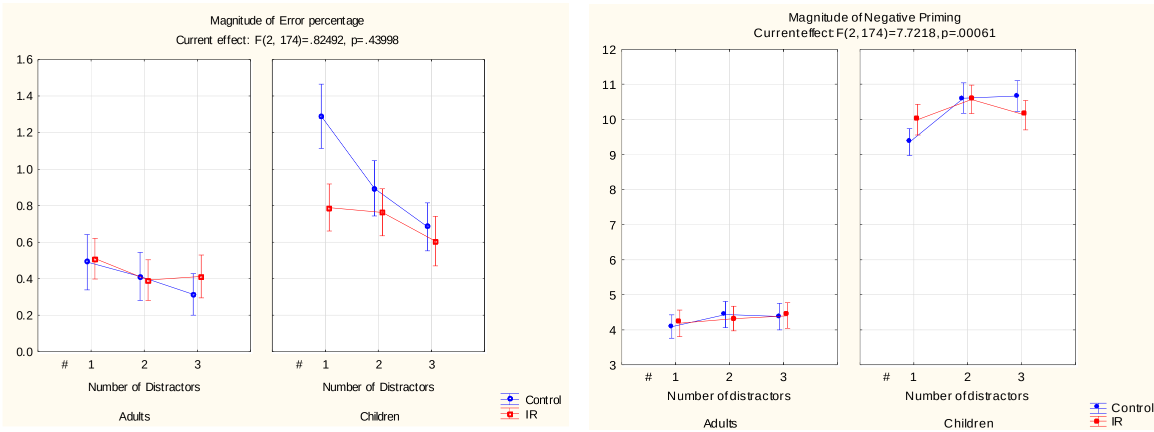

Figure 5. Age group as a function of priming and number of distractors. Mean reaction times (on right) and mean error percentages (on left). Error bars indicate standard errors of mean.

Discussion

Experiment 2 further attempted to examine negative priming effects and inhibition-based fan effects in both children and adults via a letters paradigm. There were hardly any differences in reaction times between Control conditions and IR conditions which suggest no negative priming effects were found using the local-global letter task. Consistent with Experiment 1, adults did not produce significant negative priming. However, children showed negative priming for one distractor letter conditions and positive priming for the three distractor letters conditions. There was a speed accuracy trade off in the one distractor letter conditions for children. The error rate for C1 was very high for children whereas the reaction times for C1 were faster compared with C2 and C3. Therefore, the reaction time results are uninterpretable.

The theory of an inhibition-based fan effect was not supported by Experiment 2. Adults showed positive priming in the two distractor letters conditions and the three distractor letters conditions, while children showed positive priming in the two distractor letters condition. Despite the fact there was a decrease in the magnitude of negative priming from one distractor letter conditions to two distractor letters conditions for both adults and children, the results were once again uninterpretable because positive priming should not occur. Children's' results showed that the magnitude of negative priming in the three distractor letters conditions was smaller compared with the magnitude of negative priming in the one distractor letter conditions. However, considering that there was an identifiable speed accuracy trade-off for the one distractor letter conditions in children, this cannot be interpreted as an inhibition-based fan effect.

General Discussion

The two experiments in this study were designed to analyse the development of and differences in the inhibitory process in children and adults. There were three primary aims relevant to current issues in the developmental and inhibitory literature: (a) to examine inhibitory selective attention mechanisms in children and adults using both a flanker type colour blob task, and a local-global letters task, (b) to determine whether children and adults show an inhibition-based fan effect in the colour blob and the local-global letter task, and (c) to test for potential interactions between age, stimulus types, and number of to-be-ignored distractors in the magnitude of the inhibition-based fan effect.

Several important findings emerged from the current investigation. Most important, and consistent with previous research (Frings et al., 2007; Pritchard & Neumann, 2004), is that the results show significant negative priming effects in children. Children as young as 7 years of age produced negative priming using the colour blob flanker task. The results showed that children did not only respond more slowly on IR conditions but also made more errors on IR conditions. Frings et al. (2007) also confirmed this finding and Tipper et al. (1989) has now been challenged by three independent studies showing significant negative priming effects in children. The present Experiment 2 did not show statistically significant negative priming effects in both adults and children. However, using only the first half of the data, results showed that participants responded more slowly on experimental conditions (IR). Children also showed on average a longer response time for IR1 and IR2 compared with C1 and C2 in Experiment 2.

Negative priming effects have been reliably demonstrated by adults in a variety of tasks involving a wide range of stimuli such as Stroop items, words, letters, pictures, and novel shapes (Pritchard & Neumann, 2004). However, the present results were not consistent with past findings on negative priming effects in adults. The design of the current Experiment 1's stimuli was the same stimuli used in the flanker-type colour blob task in Frings et al. (2007). Frings et al. (2007) found negative priming effects in adults which were comparable with their children's results for negative priming effects. Pritchard and Neumann (2009) used the same flanker-type colour blob task and the present study's Experiment 1, C1 and IR1 were identical to Pritchard and Neumann's (2009) Experiment 2. The adult results from Pritchard and Neumann (2009) failed to reach significance when tested for negative priming effects which is consistent with the adults' results in this study. However, after using transformed reaction data, Pritchard and Neumann (2009) found intact negative priming effects in adults.

In the current Experiment 1, the adults' results failed to show negative priming effects even after using transformed reaction data. One possible explanation for this result is that in the one distractor colour conditions, the blob sets were always staggered to appear slightly to the left or right of each other. An adult participant might have noticed that the distractor colours would become the next subsequent target as the target in the probe display is always closer to the prime distractor colour blobs in IR1 conditions (see Figure 2). In addition, the current Experiment 1 consisted of twice as many stimuli compared with Pritchard and Neumann's (2009) experiment which means that after going through several cards, some adult participants might notice the relationship between the prime and the probe displays in IR1.

This was supported by the two separate analyses that were performed on the adults' data. Adults' data were divided in half and were analysed individually. The first half of the data showed that adults reacted more slowly on the IR2 condition compared with the C2 condition and the results were the same for the IR1 condition and the C1 condition but the effect was not as strong as the two-distractor conditions. In the second half of the data, adults reacted faster on the IR1 condition compared with the C1 condition (positive priming) and reaction time was only slightly slower on IR2 condition compared with the C2 condition. The main difference between IR1 and IR2 is that IR2 consisted of two distractor colours rather than one distractor colour for IR1. This difference would eliminate or would hold off longer the possibility of adult participants noticing the relationship between the prime display and the probe display as staggering the colour blob sets would not always make the target in the probe display closer to the same coloured colour blobs in the prime display. Therefore, the current result from the second half of the data for adult participants to react faster on IR1 condition compare with C1 condition suggested that participants might have noticed the relationship between the prime trials and the probe trials.

The other finding which is fundamental to the current hypothesis is that both experiments did not produce inhibition-based fan effects. In both experiments there was no diffusion of inhibition amongst distractors, as the results show no indication of a decrease in the magnitude of negative priming as the number of distractors increased in both adults and children. It is important that the experiments used to test for inhibition-based fan effects have to successfully test for negative priming first in order to accurately calculate the magnitude of negative priming. In the current study, only the children's results in Experiment 1 show statistically significant negative priming. The current study was the first attempt to test inhibition-based fan effects in children and the results suggested that children might not show intact inhibition-based fan effects compared with adults. However, the results cannot be interpreted conclusively as there was also no inhibition-based fan effects or significant negative priming effects found for adults, and the results do not support the current hypothesis as the current overall results showed positive priming in both experiments.

Stablum, Ricci, Pavese and Umilta (2001) used a local-global letter tasks similar to the current Experiment 2 and found intact negative priming in 24 adults which contrasts with the current results. Stablum et al. (2001) were interest in the relation between selection difficulty and negative priming and they found several interesting results that are relevant to the current research. Stablum et al. (2001) found that responding to the global level was faster than responding to the local level which supported Navon's (1977) original hypothesis on local-global stimuli. In the present Experiment 2, participants only had to respond to global levels which could be one of the explanations why the results were not statistically significant. Stablum et al. (2001) were interested in the manipulated difficulty of selection. In their Experiment 1 and 5, in which participants were exposed to the prime and probe longer compare with Experiment 2, 3, and 4, they found the magnitude of negative priming was significantly greater for the local attention condition than for the global attention condition. This result replicated the results of other studies that negative priming was greater when selection for the relevant stimulus dimension was harder (Fox, 1994; Lowe, 1979; Neill, 1977; Neumann, Ruthruff & Miller, 1995).

Despite the present experiments' lack of support for the inhibition-based fan effect hypothesis, it should be noted that the predictions from this hypothesis have recently gained independent support (Radvansky & Tamplin, 2013). Radvansky and Tamplin (2013) rediscovered and supported the inhibition-based fan effect using what they refer to as *the hydrogen model*. The hydrogen model is a simple assessment model of memory retrieval that includes a single activation component and a single suppression component during retrieval. Radvansky and Tamplin (2013) found that the effects of suppression were diffused as the number of competing distractors increased. They tested the fan effect/negative priming effect using a recognition test that involved memorizing lists of sentences about objects and locations (E.g. the potted palm is in the hotel). A given target sentence (the potted palm is in the hotel) was involved in both the experimental and control conditions. Because the sentence contains an object that was in at least one other location, this results in interference from the related but irrelevant situation models (sentences shares a concept but refers to different situations). In the experimental condition, the target probe required the retrieval of one of the related but irrelevant situation models from the previous trial because it contained the object (the potted palm) from the prime trial. For example, the potted palm is in the museum. In the control condition, the target (the potted palm is in the hotel) was the same as that in the experimental condition, but the probe was unrelated to the target (e.g. the wall clock is in the movie theatre). Radvansky and Tamplin (2013) selected out those trials on which there were either one or two competitors and involved the same target items with primes that had either two or three competitors. The results showed that the inhibition effect was smaller when there were more competitors/distractors.

Radvansky and Tamplin (2013) used a different task from Neumann and DeSchepper (1992) to support the idea of an inhibition-based fan effect. Radvansky and Tamplin (2013) reported that “suppression is divided among the distractors, there is less suppression when there are two distractors than when there is only one distractor” and that “the single competitor is supressed more than the dual-competitor trace”. These are essentially the same characteristics of the inhibition-based fan effect. In fact, it is the central prediction inherent in the inhibition-based fan effect conjecture. In their seminal study, Neumann and DeSchepper (1992) reported the finding that the “negative priming effect attenuated as the number of distractors in the previous display increased”. In addition, Neumann et al. (1993) reported the analogous finding using a modified Sternberg-type short-term memory scanning task. These studies outlined the plausibility and initial support for the inhibition-based fan effect. It also appears to be generalizable, with the recent supporting evidence from Radvansky and Tamplin (2013), even though the findings in the current study failed to support it.

In conclusion, the current study was interested in the developmental factors involved with negative priming, and potential diffusion of inhibition, as negative priming has only recently been found to be intact in children. Testing the inhibition-based fan effect in children was intended to extend knowledge about the relationship between the possible diffusion of inhibition amongst distractors due to a proposed limited capacity inhibitory resource pool and development (Neumann & DeSchepper, 1992). However, the relation between limited capacity inhibition and negative priming appears to be indeterminate based on the present findings. Additional research pursuing inhibition-based fan effects across the age span seem warranted, however, especially in light of the recent independent discovery of such effects by

Radvansky and Tamplin (2013). In line with Pritchard and Neumann (2004) and Frings et al. (2007), there was evidence for the claim that selective control mechanisms are developed much earlier in young children than previously thought. However, the current research did not find support for an inhibition-based fan effect, but his may have been due to problems with the experimental design. Further research could reduce the amount of stimuli cards used for each condition. Furthermore, using a different pool of participants for the two experiments might decrease the likelihood of interference between experiments. Although the current results failed to find evidence for an inhibition-based fan effect in children or adults, support was found for the claim that inhibitory processes develop early in life.

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